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Gulf Region

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Science Advisory Report 2012/016

# ASSESSMENT OF WINTER FLOUNDER (*PSEUDOPLEURONECTES AMERICANUS)* IN THE SOUTHERN GULF OF ST. LAWRENCE (NAFO DIV. 4T)

*Photo: Claude Nozères*

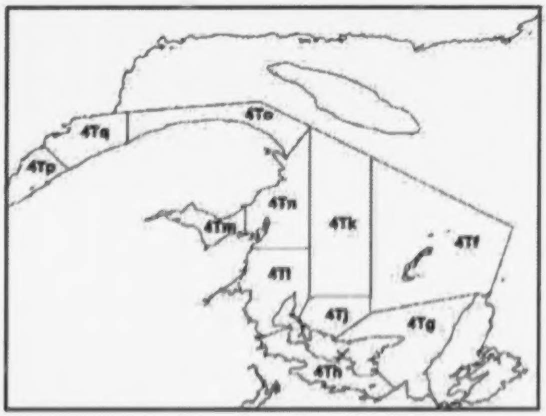


*Figure 1: Gulf of St. Lawrence and adjacent areas showing NAFO Divisions.*

## Context

*Winter flounder occurs throughout the shallow waters of the southern Gulf of St. Lawrence (NAFO Division 4T). Winter flounder is a year-round resident of the Gulf and populates inshore waters. Although the flesh of winter flounder is of good quality, the market demand for their filets is limited and in many parts of the southern Gulf, the resource is esteemed more for its qualities as lobster bait. In some areas and in some seasons, alternative baits, such as herring and mackerel, are unavailable. It has been exploited for at least 50 years in the southern Gulf, supporting localized fisheries for lobster bait and limited food markets. It has also been a by-catch of fisheries for Atlantic cod, white hake and American plaice in the past, but for the past two decades it has been exploited mainly in directed fisheries.*

*The 4T winter flounder fishery came under quota management in 1996 following closure of the Atlantic cod fishery in 1993. This measure was undertaken mainly to limit catches if a redirection of fishing effort took place. The first assessment of the status of this resource was undertaken in 1994 and the most recent in 2002 (Morin et al. 2002). An update of information on landings and survey indices was made in 2005 (DFO 2005).*

## SUMMARY

- Winter flounder annual landings in NAFO 4T reached over 3,000 tonnes in the 1960s, but varied widely due to unreliable catch statistics up to the mid-1990s. Landings declined since the early 1990s to less than 200 tonnes in 2007 and 2008. The decline in landings is partly attributed to reduced fishing effort, brought on by market conditions and the cost of fishing. A TAC of 1,000 tonnes has been in effect since 1996.



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- Approximately 300 tonnes of winter flounder were caught in 2010 and 2011. Fishing effort and catches have concentrated around the Magdalen Islands where a lack of alternative sources of bait for the lobster fishery has led to a high demand for winter flounder.
- Catch rates in a survey conducted yearly since 1971 indicate that the number and biomass of 4T winter flounder were highest before the mid-1980s. The stock declined and over the past two decades, the abundance index has varied without a clear trend near the long-term average. The survey biomass index in the 2011 survey was the lowest on record.
- The size composition of the winter flounder stock is represented by progressively fewer large fish and a growing proportion of small winter flounder <20 cm in length. The shift towards smaller fish size has been accompanied by a reduction in the size and weight-at-age.
- Total mortality (Z) was estimated directly from survey data for winter flounder aged 7 years and over. Z was over 1.0 for most of the 1970s and 1980s and less than 1.0 since the 1990s. The last estimate of Z was 0.56, in the early 2000s.
- Catch rates in the mobile gear Sentinel survey of 4T indicate that the abundance and biomass of winter flounder have declined since 2003. A trawl survey of Northumberland Strait, conducted yearly from 2000 to 2009, provided no clear trend in winter flounder abundance or biomass, but suggests that the strait may be subject to periodic influxes of young winter flounder.
- An age-structured population model indicates that the spawning stock biomass (SSB) of 4T winter flounder has peaked in regular intervals, but with an overall decline since 1973. The age composition of the SSB became dominated by young, 3 to 5-year-old winter flounder after the early 1980s. Recruitment at age-3 increased sharply in the 1980s to a peak in the 1990s and early 2000s, but has been in a declining trend in the 2000s.
- Model estimates of fishing mortality (F) fluctuated due to the landings statistics. F was concentrated on winter flounder aged 6 years and over and increased continuously to a peak of 0.06 in the mid-1980s.
- Natural mortality (M) on 3 to 8-year-old winter flounder increased from the early 1970s to the early 1990s and has remained high (>1.0). M on fish age-9+ years was above 1.5 in the mid to late 1970s and then declined to levels near 0.2 in the early 2000s. While it is possible that estimates of M may be confounded with catch misreporting, particularly of older fish, grey seals are an important predator of winter flounder and may be a contributing factor to the increasing trend in M.
- Natural mortality is driving the dynamics of the 4T winter flounder stock. The stock has also undergone a loss of productivity due to changes in the size composition and declining size-at-age. These factors, combined with declining SSB and recruitment, paint a pessimistic outlook for an increase in stock abundance in the short term.

# BACKGROUND

## Species Biology

Winter flounder (*Pseudopleuronectes americanus*) is a widely distributed flatfish found in the Northwest Atlantic, from Labrador southward to Georgia. Inhabiting mainly shallow coastal waters, winter flounder in the southern Gulf of St. Lawrence (NAFO division 4T) are limited to the Magdalen Islands and the southern parts of the Gulf: the Chaleur Bay, the Shediac Valley-Miramichi area, Northumberland Strait, and St. George's Bay. They tolerate a wide range of water temperatures and are capable of inhabiting sub-zero water conditions due to serum

antifreeze proteins that lower the freezing point of their blood to about -1.4°C. Winter flounder do not leave the Gulf in winter or migrate to deep water; they overwinter in estuaries or coastal areas. Spawning occurs in late winter or early spring. Female winter flounder release several hundreds of thousands of eggs that settle to the bottom, adhering to rocks and vegetation. The larvae drift in surface waters before metamorphosis. Winter flounder feed opportunistically on a variety of benthic organisms, mainly mollusks and small crustaceans. They also feed on the eggs of other spawning fish, in particular capelin and herring.

## The Fishery

Winter flounder landings have varied widely since 1960, reaching over 3,000 tonnes in the mid-1960s to a maximum of 4,412 tonnes in 1965; they have been mostly in decline since 1991 (Figure 2). At less than 1,000 tonnes since 1998, landings reached lows of 193 tonnes and 197 tonnes in 2007 and 2008, respectively. Preliminary landings for the 2011 fishery indicate 302 tonnes, far below the long-term average of 1,481 tonnes. The total allowable catch (TAC) was set at 1,000 tonnes in 1996, and has only been exceeded once in 1997 (1,129 tonnes).

*Table 1. Total allowable catch (TAC; thousand tonnes) and landings (thousand tonnes) for the winter flounder fishery.*

| Year | Average 1981-1990 | Average 1991-1995 | Average 1996-2000 | Average 2001-2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| TAC | na | na | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Landing | 1.7 | 1.5 | 0.8 | 0.4 | 0.25 | 0.19 | 0.2 | 0.2 | 0.3 | 0.3 |

[1] Data for 2011 are preliminary

The variable pattern of landings has been attributed partly to unreliable catch statistics. Incomplete landings data might have been a result of winter flounder employed for personal use as bait or for private sale, reported as unspecified flounder, or misreported as other species. Catch statistics were improved with mandatory logbooks for commercial fishing of groundfish starting in 1991, and better identification of the species caught. In addition, mobile gear logbooks and purchase slips began in the same year to indicate winter flounder as a landed species.

Otter trawls have been the dominant gear used to capture winter flounder in the commercial fishery. Gillnets have grown in importance over the years, peaking in the mid-1990s due to the growth of tangle net (modified gillnets) fisheries. From 1993 to 1999, gillnets contributed from 30-46% of annual landings, but their contribution has since declined to roughly 20% of winter flounder landings. Seines have varied in importance in this fishery, rarely contributing more than a quarter of annual landings. Seining is presently an important source of winter flounder catch in the Magdalen Islands fishery.

The fishery is conducted mainly from May to October, but in areas such as the Magdalen Islands where a spring lobster fishery occurs, winter flounder fishing may begin in April when conditions permit. The fishery has declined in almost all unit areas of 4T (Figures 1 and 3), but has become increasingly concentrated in the waters surrounding the Magdalen Islands (4Tf) (Figure 3). This local fishery accounted for the 246 tonnes landed in 4Tf in 2011, out of the 302 tonnes landed in 4T.

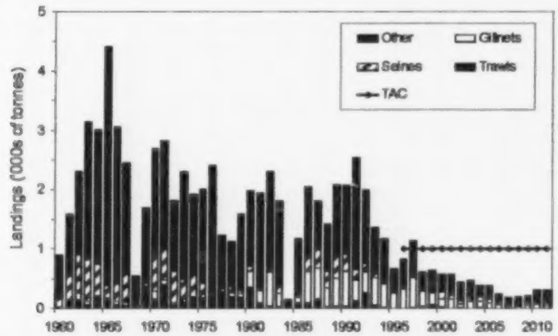



*Figure 2. Landings by fishing gear and TAC overall for the 4T winter flounder fishery.*

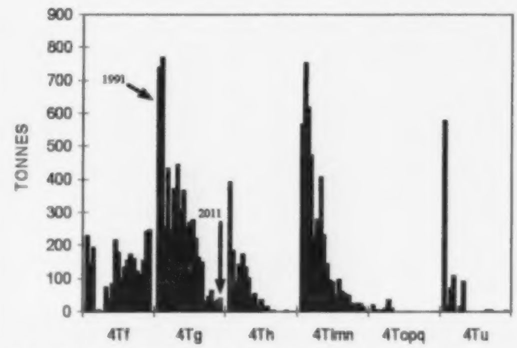



*Figure 3. Landings (t) by sub zones (unit 4Tu = unknown area), for 1991 to 2011.*

The Magdalen Islands lobster fishery considers the local stocks of flatfish as a necessary and high quality source of bait. In 2001, fishery managers authorized an experimental bait fishery for flatfish. The main gear used in this fishery was the otter trawl, scaled to operate from small lobster vessels and equipped with codend mesh sizes that were smaller than authorized in the commercial fishery for the same species. As fishing effort on winter flounder declined throughout NAFO 4T, it increased in 4Tf due to the Magdalen Islands fishery (Figure 4). In 2001, roughly 20 vessels were active in this fishery, catching about 11 tonnes of winter flounder, or 6% of the local fishery (DFO 2010). This activity increased over time and peaked in 2010 with 96 lobster boats with bait permits reporting 117 tonnes. A decision by DFO was made in December 2010 to reduce the number of bait permits and the days of fishing and to terminate the experimental bait fishery by 2013.

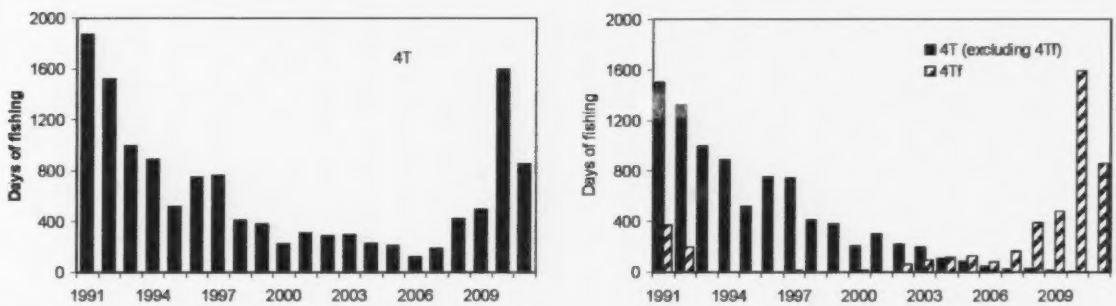



*Figure 4. Fishing effort (days) by trawlers directing for winter flounder in 4T (left panel) and in 4Tf compared to other unit areas of NAFO 4T (right panel).*

# ASSESSMENT

## Stock trends and current status

### Research vessel data

Abundance indices and the population structure of 4T winter flounder have been estimated through annual trawl surveys conducted every September since 1971. The survey is conducted using a stratified random design with the 4T survey area divided into depth-related strata. The survey has two series of indices: one that includes 24 strata (years 1971-2011) and the other

that includes the three additional inshore strata (1984-2011). The 2003 survey is removed from the data series due to failure of the research vessel and incomplete coverage. Comparative fishing experiments were conducted when research vessel was changed. These experiments have established the relative efficiency of gears and have made it possible to adjust catch rates when required.

The catch rates of winter flounder in this survey were highest before the mid-1980s, by both numbers and weight of winter flounder caught (Figure 5). The mean number of winter flounder has tended to fluctuate near the long-term mean catch (39 fish per tow) without a clear trend. It is more apparent from the mean weight of catches that the stock has declined since the late 1980s. The lowest weight per tow (1.9 kg) was recorded in the 2011 survey, well below the long-term average (9.1 kg per tow).

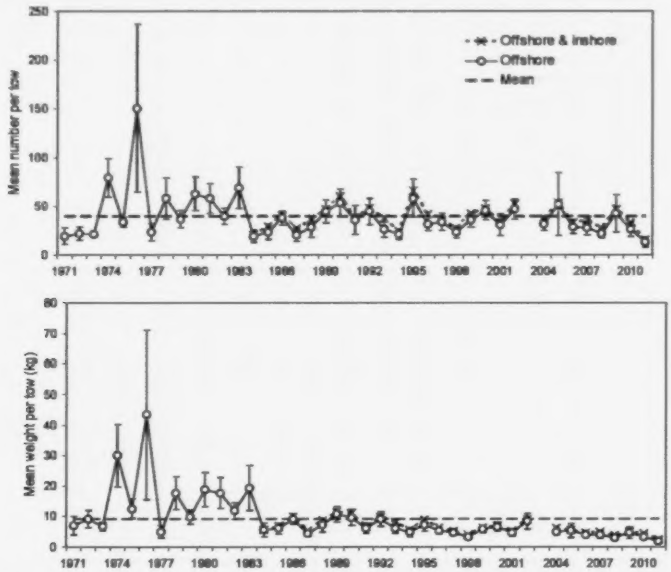



*Figure 5. Survey catch rates by number (upper graph) and weight (lower graph). Data points joined by broken line indicate catch rates that include inshore strata sampled since 1984. The horizontal dashed lines represent the average of annual estimates from offshore strata since 1971.*

Winter flounder length frequencies in the survey catch are typically unimodal and show no distinct length modes that would indicate the presence of strong or weak cohorts. Winter flounder <20 cm, uncommon in surveys of the 1970s, increasingly dominated catches in the 1990s and 2000s. The size distribution of winter flounder in 4T is characterized by a loss of large fish and a progressive shift towards smaller sizes (Figure 6).

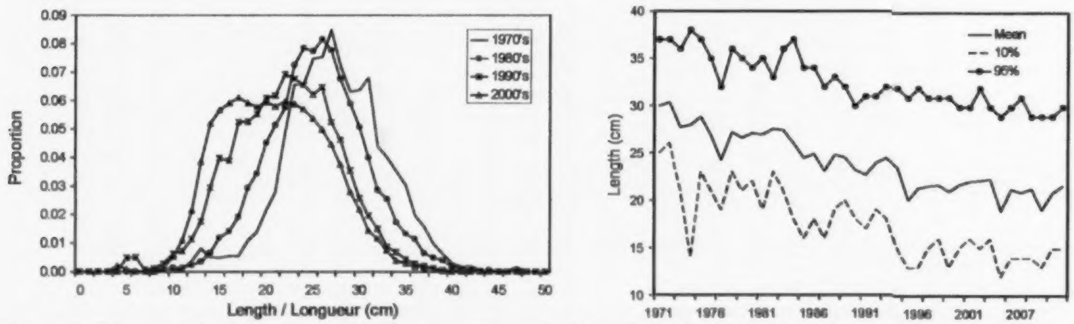



*Figure 6. Changes in the survey size composition of winter flounder, showing decadal changes in the proportion of fish at length (left panel) and changes in mean length and the 10th and 95th percentiles of fish length (right panel).*

Biological sampling on surveys provides information on the sex, age and maturity stage as a function of fish length. The survey population-at-length was converted to population-at-age using age-length keys established from these surveys. As age determinations were only available for certain years (1975, 1977-1982, 1990-1993, 1997, 2004-2007), the age-lengths keys available were used to estimate the years without age determinations. The growth in size of winter flounder was approximated from observed annual length-at-age data and by applying the von Bertalanffy growth function to age-length keys. Across all ages, the stratified mean length and the estimated lengths from the growth function indicate that the size at age has declined over time (Figure 7). Figure 7 also shows the declines in the estimated weight of 8-year-old winter flounder, typical of a general loss of productivity due to growth in the 4T winter flounder stock.

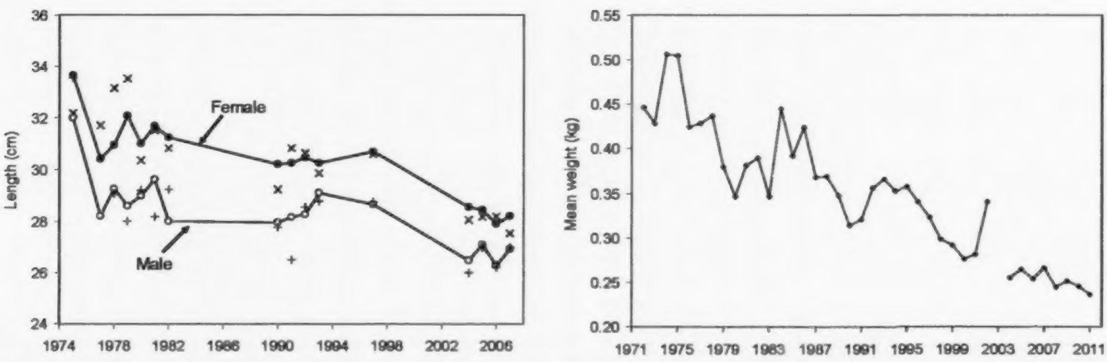



*Figure 7. Changes in the size-at-age of 4T winter flounder. Panel at left shows mean length of 8-year old winter flounder observed (points) and estimated (lines) from a growth model. Panel at right shows trends in the mean weight of 8-year old winter flounder (sexes combined).*

The survey population-at-age (estimated for years without concurrent age data) had a declining modal age, as expected from the population shift towards smaller size. Until 1983, modal age tended to centre on 6 years-of-age, then age-5 until 1994, followed by age-4 fish.

Total mortality (Z) was estimated from the survey population-at-age data as the slope of log-transformed catch in relatively short time periods, accounting for variation in year-class abundance. Z was calculated in 5-year time periods and for ages 7 years and over. The model resulted in 27 significant estimates of Z, from periods 1973-1977 to 1999-2003. Estimates of Z varied between 1.02 and 1.47 through the 1970s and 1980s, with the exception of the 1977-

1981 period when it was estimated at 0.61 (Figure 8). Z has been below 1.0 through most of the 1990s and was estimated at 0.59 in the 1999-2003 period.

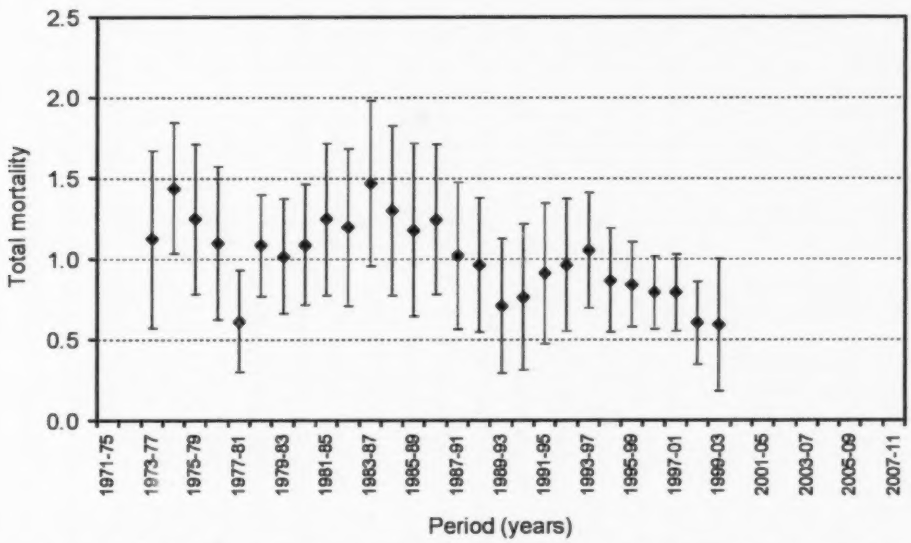



*Figure 8. Total mortality (Z) on 4T winter flounder aged 7 years and older based on survey data. Points represent estimated Z; vertical bars are 95% confidence limits.*

Winter flounder is a coastal species that spawns nearshore, overwinters in the southern Gulf and makes limited seasonal movements. It is important to recognize that their distribution is at the inshore limit of the main survey coverage (Figure 9), so it is possible that the annual survey index fails to take into account seasonal or annual variations in their distribution. It is also possible that the 4T management area comprises several spawning populations of winter flounder, partially connected through larval drift or other mechanisms of exchange from one area to another. Figure 10 shows survey indices for stratum groupings, indicative of some degree of variation in subarea abundance trends.

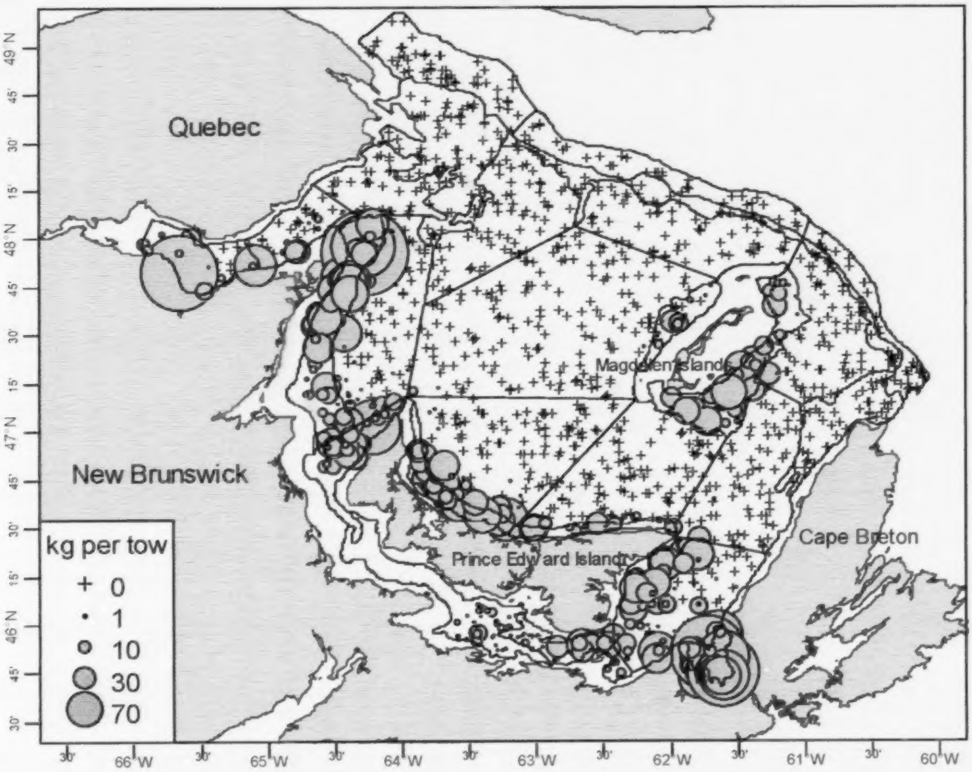



*Figure 9. Standardized catches of winter flounder in surveys conducted since 2002.*

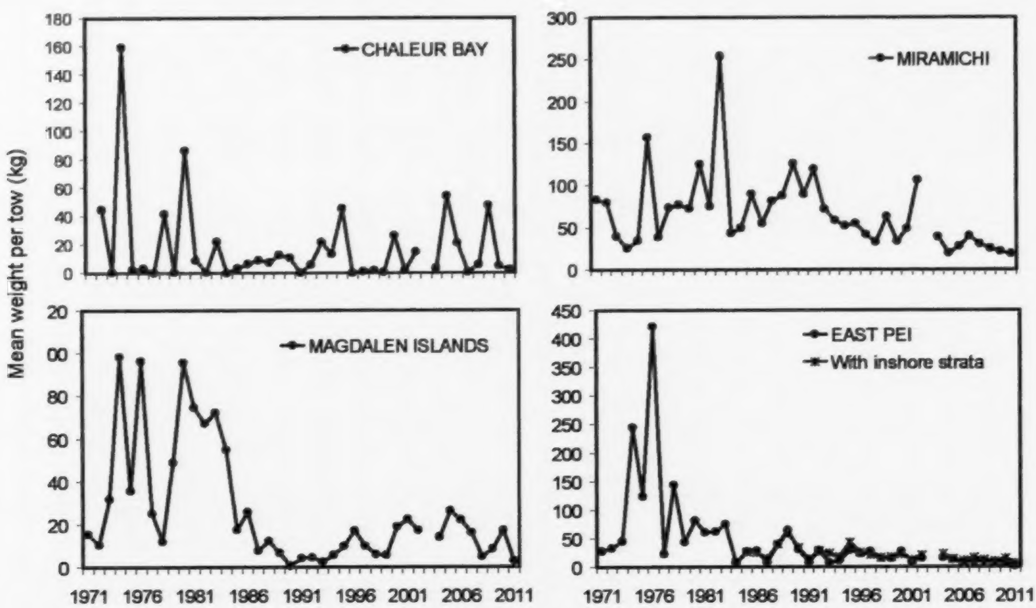


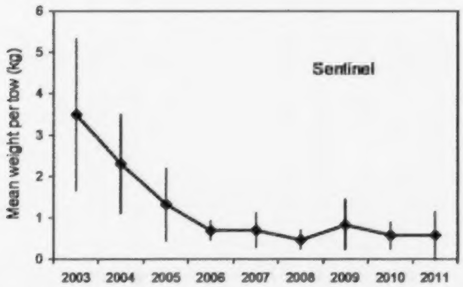

*Figure 10. Trends in winter flounder mean catch weight (kg) per standard tow in stratum groupings of the annual 4T survey.*

The Chaleur Bay area is covered by two strata that include a range of depths, leading to high variability in the survey index and difficulty in discerning a clear trend (Figure 10). The Miramichi area, including strata off the coast of northern New Brunswick, increased over the 1970s and 1980s, with a declining trend in the winter flounder biomass index since the early 1990s. Data on winter flounder in strata surrounding the Magdalen Islands and off eastern PEI indicate similar biomass trends, with high levels recorded early in the time series up to the early or mid-1980s, with low biomass since then.

Other surveys

The Sentinel Program was initiated in 1994 to monitor the southern Gulf cod stock. In 2003, the mobile gear program adopted the same stratified random sampling design as in the annual ecosystem survey. Four vessels participate each year in the survey using standardized gear and fishing procedures.

The distribution of winter flounder in the mobile gear sentinel program was comparable to that of the annual ecosystem survey. Sentinel catch rates declined from 2003 to 2006, followed by a consistently low level of stock abundance and biomass from 2006 to 2011 (Figure 11). The length frequencies of winter flounder in the sentinel program were unimodal and did not reflect incoming recruitment modes.



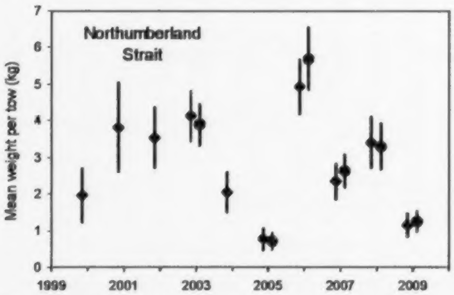




*Figure 11. Biomass indices from Sentinel survey (NAFO 4T coverage; left panel) and Northumberland Strait survey (right panel). Vertical bars represent approximate 95% confidence intervals. Round symbols indicate estimates with extended coverage of Northumberland Strait.*

The Northumberland Strait survey began in 2000 with the primary purpose of monitoring American lobster abundance and recruitment. It was conducted yearly in July-August until 2009 with standardized gear and sampling procedures. This survey covered inshore areas to depths <10 m, a habitat that is occupied by winter flounder and that is not fully covered in the annual ecosystem survey. The survey area was divided into five strata, of which the most eastern one was sampled beginning in 2003 and from 2005 to 2009. Sampling was incomplete in key areas of the strait in 2002 and 2005, leading to possible bias in the indices for those years.

Winter flounder were distributed throughout Northumberland Strait, but were most abundant in the northwestern part of the strait across all depths and in the shallow waters east of Pictou (NS). Large fluctuations in abundance and biomass indices were observed. The most notable year effect occurred in 2006, when winter flounder appeared in increased abundance and biomass throughout Northumberland Strait. This increase could not be attributed to a recruiting size class. Length frequencies from this survey were dominated in most years by a single mode of winter flounder between 12 and 20 cm.

Northumberland Strait appears to be a dynamic area of the southern Gulf, with periodic influxes of winter flounder. In general, there was not apparent trend in abundance, biomass or length composition of winter flounder in this survey over the 10-year period of this survey.

### Population model

Population modelling was undertaken to improve understanding of the implications of the changes in the size structure of southern Gulf winter flounder observed over time. The model used was Virtual Population Analysis (VPA). Inputs to this model were the commercial catch-at-age, derived from commercial length frequencies obtained through port sampling and at-sea observers, converted to age using survey age-length data. Data on the length composition of commercial catches were available since 1973. The other model input was the estimated survey population-at-age obtained from the annual ecosystem survey. Winter flounder aged 3 years and older were included in the model; the oldest age consisting of all fish 14 years and older (age 14+ years).

The model estimated the instantaneous rate of natural mortality (M) annually for two age groups: winter flounder of ages 3-8 and 9+ years. The parameters estimated by the model included the abundance of winter flounder aged 4 to 14+ years in 2012, annual estimates of M for each age group, and catchability (q) of the survey trawl. The parameter q relates the survey catch to the estimated population at each age. It was constrained on a logarithmic scale to values corresponding to less than 0.01 to 0.67. The upper range was considered reasonable given the efficiency of the survey trawl and the limited shoreward extent of the survey coverage.

The survey indices of abundance at age varied widely, particularly among younger ages in the 1990s and 2000s and at older ages before the mid-1980s. However, in the aggregate the model estimates matched the trends in q-corrected abundance indices closely (Figure 12).

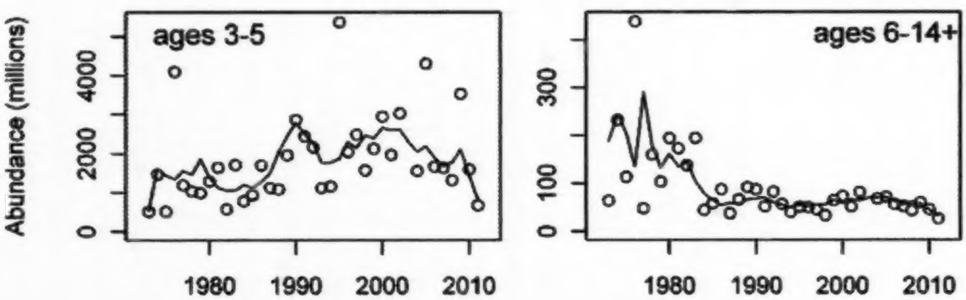



*Figure 12. Comparison of model estimates of abundance for two age groups adjusted to September (lines) and q-corrected survey abundance indices (circles), 1973-2011.*

The spawning stock biomass (SSB) has peaked in roughly 10-year periods since 1973, but with an overall declining trend (Figure 13). The age composition of the SSB has changed considerably since 1973, becoming increasingly dominated by young fish (ages 3 to 5) since the early 1980s. The estimated abundance of age-3 recruits increased sharply in the late 1980s, with peaks in the 1990s and early 2000s (Figure 13). There appears to be a declining trend in recruits since the early 2000s.

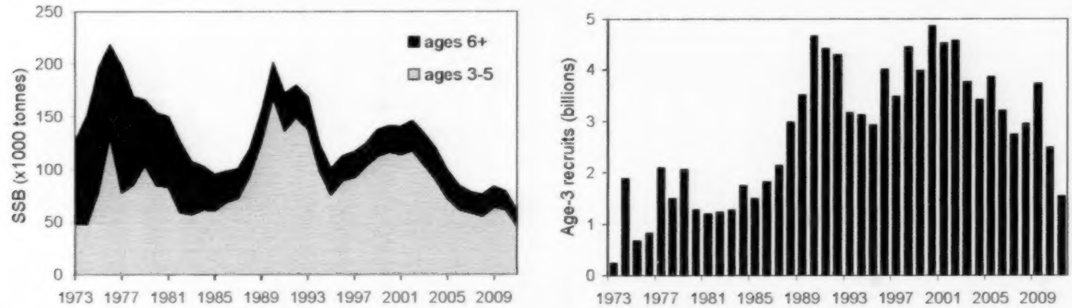



*Figure 13. Area plot of estimated spawning stock biomass (SSB) for ages 3-5 years and ages 6 years and older (left panel) and abundance of age-3 recruits (right panel) of winter flounder.*

Estimates of fishing mortality (*F*) tended to fluctuate widely between years, likely due to errors in the catch (Figure 14). F on age 3-5 winter flounder has been low in all years; however, it appears to have declined from a high in the late 1970s to near zero in the 2000s. F was concentrated on winter flounder aged 6 years and over, increasing continuously to the late 1980s, with a peak of 0.06 in 1986. The large drop in F in 1984 is interpreted as being due to incomplete catch reporting.

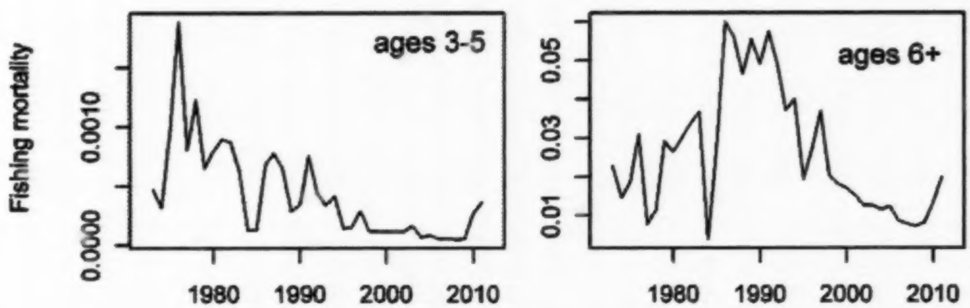



*Figure 14. Estimates of the instantaneous rate of fishing mortality (F) of winter flounder for age groups 3 to 5 years old (left panel) and ages 6 years and older (right panel).*

Natural mortality was the main component of total mortality on all ages of winter flounder throughout the time series. For ages 3-8 years, M increased from the early 1970s to the early 1990s, remaining above 1.0 since then (Figure 15). Older winter flounder experienced M above 1.5 in the mid to late 1970s and then declined to levels near 0.2 in the early 2000s. While it is possible that estimates of M may be confounded with misreporting, particularly of older fish, grey seals are an important predator of winter flounder (Hammill 2011).

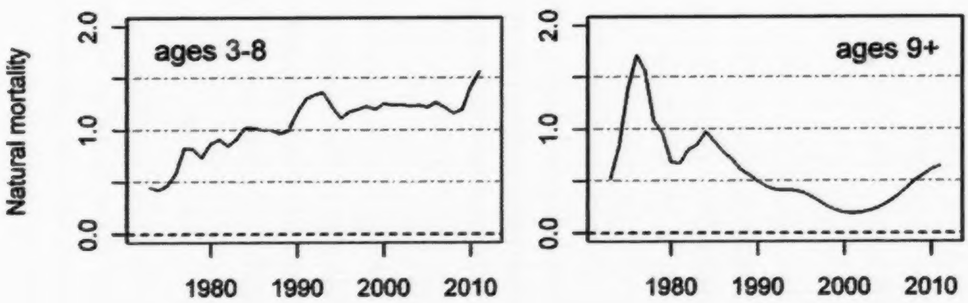



*Figure 15. Estimates of the instantaneous rate of natural mortality (M) of winter flounder for age groups 3 to 8 years old (left panel) and ages 9 years and older (right panel).*

## Sources of Uncertainty

Several biological characteristics of 4T winter flounder are not fully known. This assessment presents data on the age composition of commercial and survey catch-at-age; however, age determinations were only available for 16 of 40 years of survey data (2003 survey excluded). This was resolved by applying combined age-length keys to years without appropriate data. No age determinations have been made on winter flounder otoliths collected from commercial fisheries. More ageing information would improve estimates of the age composition and resulting estimates of mortality and growth.

A constant maturity schedule was assumed for winter flounder, based on 1975 to 1982 samples. Limited data obtained since that period suggest that this may be an appropriate assumption; however, further validation is required.

Stock structure is a source of uncertainty for this resource. Winter flounder have a discontinuous, nearshore distribution and some known traits, such as their adhesive eggs and the limited movement of tagged animals, suggest that there may be local breeding populations within 4T. Some degree of mixing may be expected due to the pelagic larval stage and straying of adult winter flounder.

The annual surveys of 4T do not sample the full distribution of winter flounder. Small, young winter flounder are found shoreward of the area sampled by the survey. Catch rate analyses of the annual survey assume that unsampled winter flounder habitat represents a constant proportion of the total population between years. If the range occupied by winter flounder contracts and expands in relation to winter flounder density, the assumption of constant distribution would not be appropriate.

Length-frequencies of winter flounder from the research survey do not signal incoming recruitment, nor do they track size modes that indicate year-class strength. Despite these weaknesses, the annual survey provides trends in stock abundance that extend over 40 years.

Uncertainty in landing statistics, including unreported catches and possibly discarding at sea, may contribute to some high estimates of M, particularly in the period before the 1990s. Since the early 1990s, improvements were made to logbooks and several management measures were introduced (e.g. at-sea observers, dockside monitors, small fish protocols), improving landing statistics for this resource.

Catchability (q) was a model parameter, estimated over ages 3-11, which related survey catch-at-age to the estimated population-at-age. Q was constrained to be estimated within a range of values. The model estimates of q for ages 3 and 8-9 years were at the lower and upper limits of the constraints, respectively. More research is required to determine whether the estimates of q, are reasonable, particularly at younger ages, given the trawl used in the annual survey and the extent of winter flounder habitat covered by the survey.

## CONCLUSIONS AND ADVICE

Two surveys indices from NAFO 4T indicate that winter flounder has experienced both long-term and recent declines. A survey conducted yearly since 1971 indicates that winter flounder abundance and biomass was highest before the 1980s. Abundance has fluctuated near the long-term average in the past decade; however, the biomass index from this survey indicates a declining trend since the late 1980s. The lowest biomass index recorded in this survey occurred in 2011. The mobile gear Sentinel survey has recorded a decline in winter flounder abundance and biomass since 2003.

The size composition of the winter flounder population, recorded in survey data, is composed of increasingly fewer large fish and a growing proportion of small individuals. The size-at-age of southern Gulf winter flounder has declined over time. Decreases in the size and weight at age point to a loss of stock productivity.

An age structured population model for 4T winter flounder indicates that the spawning stock biomass (SSB) has peaked at intervals over the 1973-2011 period, but exhibits a strong downward trend over the past 20 years. Combined with a reduction in the SSB is a shift in the age composition of spawners from older (age-6+) fish to 3 to 5-year-old fish. Recruitment of age-3 winter flounder peaked in the 1990s, but appears to be in decline since the early 2000s.

Fishing mortality has been mainly concentrated on ages 6-11, reaching as high as 0.06 in the late 1980s and early 1990s, declining afterwards.

Natural mortality (M) appears to drive the dynamics of this stock. M on ages 3-8 has increased up to the 1990s and has remained above 1.0 since then. M on age-9+ winter flounder reached extreme values >1.5 in the 1970s, possibly due to confounding with under reported landings, declined to 0.2 in the early 2000s and has risen to 0.6 in recent years. Given the low level of harvests throughout the 2000s, grey seal predation is considered as a possible source of high M for most of the past two decades.

In view of high natural mortality and declines in growth rates of winter flounder, the prognosis is pessimistic for an increased abundance of this stock in the short term. Given the level of harvesting of winter flounder throughout most of NAFO 4T, it is unlikely that commercial harvesting at current levels will impact the resource significantly. However, the increasing demand for winter flounder for bait leaves the potential for under reporting and it will be necessary to ensure adequate monitoring of all removals.

## SOURCES OF INFORMATION

This Science Advisory Report is from the regional advisory meeting of February 23, 2012 on the Assessment of stock status of winter flounder (*Pseudopleuronectes americanus*) from the southern Gulf of St. Lawrence (NAFO Div. 4T). Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

DFO. 2005. Winter flounder in the southern Gulf of St. Lawrence (Div. 4T). DFO Can. Sci. Advis. Sec. Stock Status Rep. 2005/015: 6 p.

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